February 1971

Proposal 0112

Neutron Diffraction Dissociation and Coulomb Dissociation from Various Nuclei

Michael J. Longo, H. R. Gustafson, Lawrence W. Jones
and John vander Velde
The University of Michigan

ABSTRACT

We propose to use the 1.75 mr neutral beam in the Meson Lab to study the reaction

$$n + A \rightarrow N^* + A$$
$$\quad\quad\quad \hookrightarrow (p + \pi^-)$$

for targets with as large a range in atomic weight as possible (e.g., hydrogen through lead) and incident neutron energies from approximately 80 to 200 GeV. The aim is to study

(1) the cross section vs. energy and mass for $(p\pi^-)$ masses from 1.08 to approximately 4.7 GeV,

(2) The A dependence of the cross section from which information on N* total cross sections in nuclear matter can be extracted,

(3) the t-dependence which, for the lighter elements, gives information on nuclear structure parameters,

(4) angular distributions of the decay products from which information on quantum numbers of the N* and the exchanged particle can be extracted.

This experiment would be a natural extension of a similar experiment carried out by our group at the AGS last summer. The experience gained in the AGS experiment will be very valuable in designing an experiment for NAL.

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313-764-4443

I. Introduction

In the past few years coherent production processes off nuclei have become the subject of intense experimental and theoretical study. Such processes are typically only possible with very high energy beams and the extension of these studies to NAL energies is of great interest. The requirement that the target nucleus remain intact and in its ground state for coherence considerably restricts the quantum numbers of the particle exchanged between the beam particle and the target nucleus, thus making such processes amenable to theoretical analysis. Nevertheless there is at present relatively little data to confront the various theories,[1] and our understanding of these processes is still limited. Recent reviews of the current situation have been given by Bingham[2] and Morrison.[3]

Beams of neutral particles (γ, K°, n) are rather convenient for studies of coherent production because they can dissociate into two charged particles. We propose to use a neutron beam with a broad energy spread ($\cong$ 80 to 200 GeV) to study the process

$$n + A \rightarrow N^{*} + A$$

where the N^{*} is any excited state decaying into $p + \pi^{-}$. The angular distribution of coherently produced N^{*}'s is strongly peaked forward. If t is the four-momentum transfer to the nucleus squared, then the t-distribution is roughly exponential, i.e.,

$$\frac{d\sigma}{dt} \propto e^{bt}$$

where $b \cong 10\ A^{2/3}(\mathrm{GeV}/c)^{-2}$.

For reasonably small N* masses the opening angle of the $(\pi^- p)$ pair is rather small. [Typically $\theta_{op} \leqslant 2\sqrt{m^{*2}-1}\ /p$ where m* is the mass of the N* in GeV and p the incident neutron momentum in GeV/c.] It is therefore possible to use a spectrometer with rather small aperture to detect both the p and π^-. If the vector momenta of the p and π^- are measured all the relevant kinematical quantities can be determined; these include the momentum of the incident neutron, the N* mass, $t'=t-t_{min}$ ($\cong p_\perp^2$), the decay angle, and the angle of the decay plane relative to the production plane. The fit is with zero constraints. However the requirement that the t'-distribution must show a sharp peak whose width is characterized by the nuclear radius provides a means of estimating noncoherent background. Our experience at the AGS shows that it is indeed possible to obtain a clean signal. This will be discussed in the next section.

II. The AGS Experiment

The AGS experiment was completed last August. The data analysis is well underway, but no results have yet been published.

No other group has studied this reaction. We therefore present here a brief discussion of some very preliminary results to serve as a framework for our proposal to extend these measurements to NAL energies. Most aspects of the experiment scale readily to higher energies. Cross sections are expected to remain roughly constant between 30 and 200 GeV/c. The range of N* masses available is of course larger at higher energies.[4] In many respects the experiment is easier at higher energies.

The circumstances of the AGS experiment were somewhat unusual and deserve explanation. The experiment was undertaken without official approval upon completion of an approved experiment to study n-p charge exchange. The setup, tuning, and data taking of the diffraction dissociation experiment were carried out in a total calendar time of about three weeks. The experiment made use of equipment from the charge-exchange experiment which had to be rearranged.

Despite the severely limited running time and simple triggering arrangement we were able to record $\sim 10^6$ triggers with targets of C, CH_2, Cu, and Pb. About 10% of the triggers reconstructed to give $(\pi^- p)$ events with t and m* in the desired range. The experimental arrangement used is shown in Fig. 1. The target was surrounded by an anti-counter except for a small hole in the forward direction. The trigger was $P_1\bar{A}_1\bar{A}_2$ in coincidence with either L_1R_1 or L_2R_2. Event rates were limited only by the spark chamber recovery time. Trigger rates greater than 30 per burst could easily have been obtained.

Figure 2 shows the uncorrected incident neutron spectrum reconstructed from the carbon data. Figure 3 shows the distribution in t' for the carbon and lead data. The background under the coherent peak is $\cong$ 20% for carbon and somewhat less for lead. This may be reduced somewhat as the analysis proceeds. The exponential slope of the background is $\cong 10\ (\mathrm{GeV/c})^{-2}$, indicating that it is probably due to incoherent production from individual nucleons. The exponential slope at small t' for carbon is $\cong 49\ (\mathrm{GeV/c})^{-2}$, about that expected. For lead it is $\cong 233\ (\mathrm{GeV/c})^{-2}$, which is considerably smaller than the expected value of approximately $350 (\mathrm{GeV/c})^{-2}$. This is due at least in part to the smearing out of the peak by both the experimental angular resolution and coulomb scattering in the lead target. This emphasizes the need for good resolution and thin targets to reduce this smearing and thereby minimize the background under the coherent peak.

Figure 4 shows preliminary $(\pi^- p)$ mass distributions for a sample of our data with carbon and lead targets for events in the coherent peak. No well defined peaks appear. As has been observed in p-p experiments[5] the mass distribution is dominated by a broad peak at low masses. The requirement that the recoil nucleus remain intact puts a limit on the maximum momentum that can be transferred to the mucleus and sets an effective upper limit on m*. If we take $p_{max} \cong m_{\pi}/A^{1/3}$, for 25 GeV/c incident neutrons this is $\cong$ 1.95 GeV for carbon and $\cong$ 1.4 GeV for lead. This partially explains the paucity of events with masses of this order in the data samples presented, although for carbon the mass distribution falls off faster than would be expected from this kinematical effect and the geometrical efficiency of the apparatus.

No evidence for a peak corresponding to the $\Delta(1236)$ can be seen in the lead data. It should be possible to produce isospin 3/2 states by photon exchange. The cross section for $\Delta(1236)$ production should therefore vary as Z^2 and is expected to be sizeable for lead. The cross section for $\Delta(1236)$ production by incident neutrons has been calculated explicitly by Nagashima and Rosen.[6] It may be that when the data analysis is further along, some evidence for $\Delta(1236)$ production will be seen but at present there is no sign of it.

We are presently studying the angular distribution of the N* decay products in both the Jackson and helicity frames. This should provide information on the quantum numbers of the states involved. Preliminary results indicate that neither s-channel nor t-channel helicity is conserved, in contrast to results obtained in several other reactions.[7]. Further results from the AGS experiment will be forwarded as soon as they are available.

III. The Proposed Experiment

A. Purpose

On the basis of our experience at the AGS we have a pretty good idea of what to expect at NAL energies. It will be possible to study a much larger range of m* in the NAL experiment (up to approximately 4.7 GeV with carbon targets and 3 GeV with lead). It is possible that well-defined peaks will show up in the mass spectrum at higher energies. However even without such peaks the mass spectrum and angular distributions and their variation with energy and atomic weight are of great interest.

The chances of seeing a clean $\Delta(1236)$ peak from Coulomb dissociation at higher energies seem relatively good. The total cross section for producing the $\Delta(1236)$ is expected to increase by about a factor of five between 25 and 170 GeV/c (Ref. 6). Diffraction dissociation by "Pomeron" exchange is expected to remain fairly constant at high energies (depending somewhat on the model chosen), so it may be easier to see coulomb production of the $\Delta(1236)$ at NAL energies.

Perhaps one of the most important lessons of the AGS experiment is that one would like to obtain a really large number of events ($\geq$ 10 times the number obtained in the AGS experiment). This is basically because we are binning in a multidimensional space (incident neutron energy, N* mass, atomic weight,...). To determine the quantum numbers of the states involved it is necessary to study the angular distribution of the decay products for small ranges in m* and t'. This requires a large number of events and sensitivity over as large a range of angles as possible.

Basically then the purpose of the NAL experiment would be to obtain good statistics over as large a range of the relevant variables as possible. From this we hope to determine the following:

1) The energy dependence of the cross sections
2) The A dependence
3) The dependence on N* mass
4) The dependence on t'
5) The angular distributions of the decay products vs. mass and t'.

So little is known about these processes at present that it is hard to predict exactly where the most important physics lies. It seems reasonable to expect that such information will go a long way in furthering our understanding of coherent production processes.

B. Experimental Arrangement

We propose an experiment generally similar to the AGS experiment, but with considerable refinement in the experimental technique and at least an order of magnitude more data. The details of the experimental arrangement depend to a large extent on the availability of magnets for the spectrometer. If larger magnets are not available we envision an arrangement that would use two 24" x 72" magnets[8] with two slightly different configurations. For relatively small N* masses ($m^* \leqslant 2.0$ GeV), we would probably use a setup similar to that used at the AGS shown in Fig. 1 with distances along the beam direction scaled by a factor of approximately 6 and with two 24" x 72" magnets. For larger masses a setup like that shown in Figure 5 would be more appropriate. To cover the desired range of M* and decay angles the magnet currents and target-magnet spacing L would be varied in steps. Rates are expected to be quite high so the small solid angle subtended by the 24" x 72" magnets is tolerable, but larger magnets would obviously be preferable to reduce biases and allow a more complete coverage of masses and decay angles. The setup shown does have the advantage of flexibility. If a particular mass region turns out to be interesting it can be studied in more detail.

The proposed arrangements are not optimized and should only be considered as representative. Details would be worked out in consultation with NAL staff. A fairly modest setup is envisioned, since the experiment is basically exploratory in nature. Our requirements are summarized below:

Beam - 1.75 mr neutral beam. Neutron flux ~10^6/burst

Magnets - Two 24" x 72" (or larger) magnets for spectrometer.

Targets - Most of the running would be done with solid targets.

A hydrogen-deuterium-helium target ≈ 12" long may be used if available.

Machine time - ~300 hours tuneup, 400 hours running.

Other Requirements - A long spill is important since rates will be limited by chamber recovery time. A modest amount of fast electronics from the electronics pool will be sought. The spark chambers, on-line data acquisition electronics, and scintillation counters will be provided by the University of Michigan out of funds from an existing contract. Some use of an NAL computer for preliminary offline data analysis would be desirable.

Scheduling - We would hope to follow the Ohio State-Michigan State np charge-exchange experiment (#12) in Beam 24. Our proposed spectrometer is very similar to theirs. We could use the same magnets and possibly other apparatus.

Footnotes and References

1. See for example:

   J. S. Trefil, Phys. Rev. <u>180</u>, 1366 (1969).

   K. S. Kölbig and B. Margolis, Nucl. Phys. <u>B6</u>, 85 (1968).

   Fournier, Orsay Report LAL 1237, July 1970.

   B. Margolis, Phys. Letters <u>26B</u>, 524 (1968).

2. H. H. Bingham, CERN Report D. Ph. II/PHYS 70-60, October, 1970.

3. D. R. O. Morrison, Rapporteur's Talk at Kiev Conference, Sept. 1970; CERN Report D.Ph. II/ PHYS 70-64.

4. The condition for coherence is that

$$q\,a \leqslant 1$$

   where q is the momentum transferred to the nucleus and a is the nuclear diameter, $a \cong 2A^{1/3}/m_\pi$. The minimum four-momentum transfer squared t_{min} is

$$|t_{min}|^{\frac{1}{2}} \cong (m^{*2} - m_n^2)/2p$$

   where p is the beam momentum. The two relations lead to an effective "threshold" momentum for producing a given m*,

$$p_{th} \approx (m^{*2} - m_n^2)\, A^{1/3}/2m_\pi .$$

5. W. E. Ellis *et al.*, Phys. Rev. Letters <u>21</u>, 697 (1968).

   F. L. Berger, Phys. Rev. Letters <u>21</u>, 701 (1968).

6. Y. Nagashima and J. L. Rosen, Univ. of Rochester Report UR-875-295, Nov. 1969 (unpublished).

7. H. H. Bingham *et al.*, Phys. Rev. Letters **24**, 955 (1970).

J. Ballam *et al.*, Phys. Rev. Letters **24**, 960 (1970).

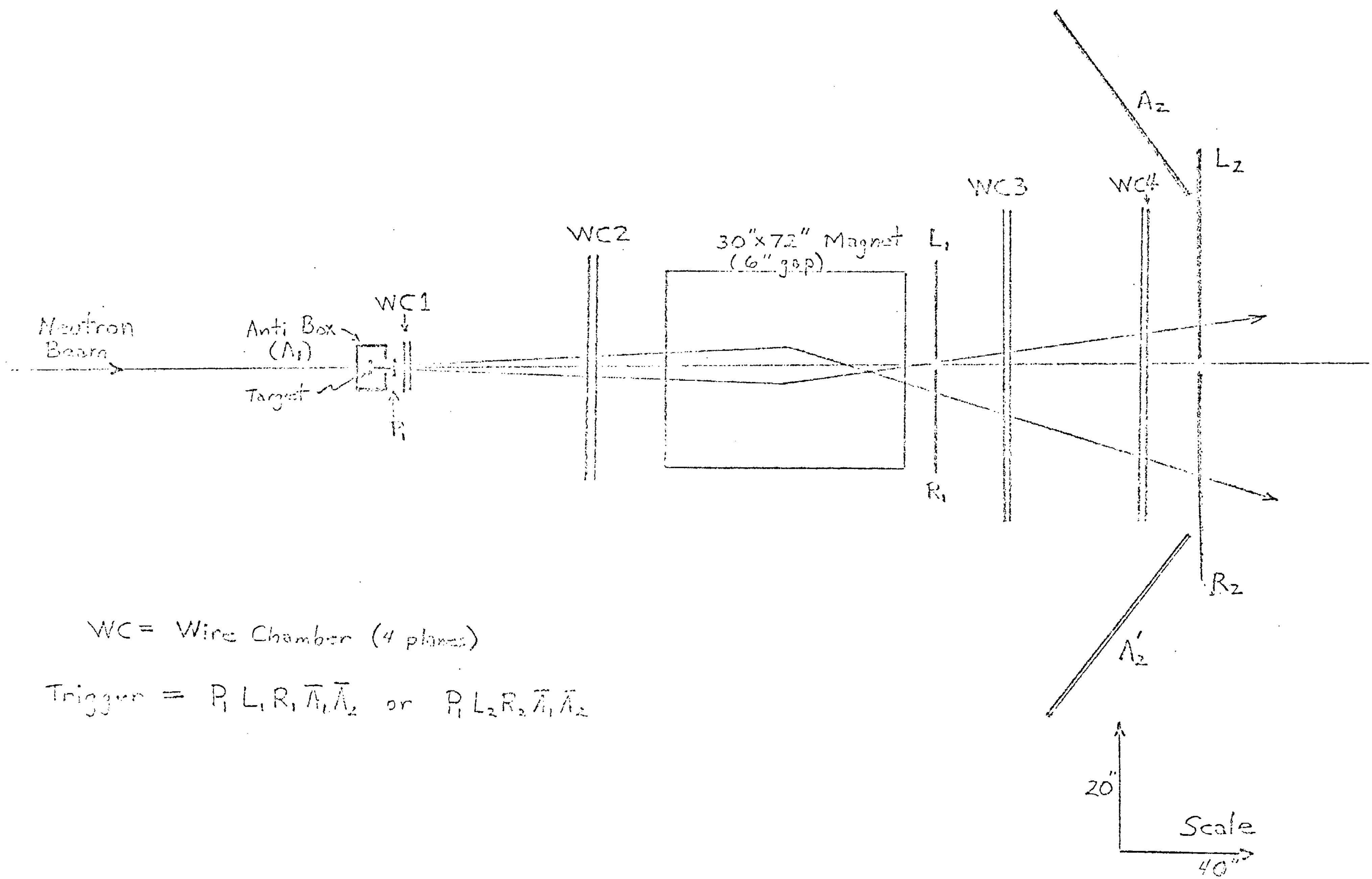
J. V. Beaupre *et al.*, Preprint, CERN/D. Ph. II/PHYS 70-65

G. Asc~~Sdv~~oli *et al.*, Preprint, Univ. of Illinois, COO-1195-204.

8. Two 24" x 72" magnets will also be used in the Ohio State-Michigan State np charge-exchange experiment which we hope to follow in the neutral beam.

Figure

Layout of AGS Experiment



WC = Wire Chamber (4 planes)

Trigger = $P_1 L_1 R_1 \bar{A}_1 \bar{A}_2$ or $P_1 L_2 R_2 \bar{A}_1 \bar{A}_2$

Figure 2

Uncorrected
neutron spectrum
from carbon target

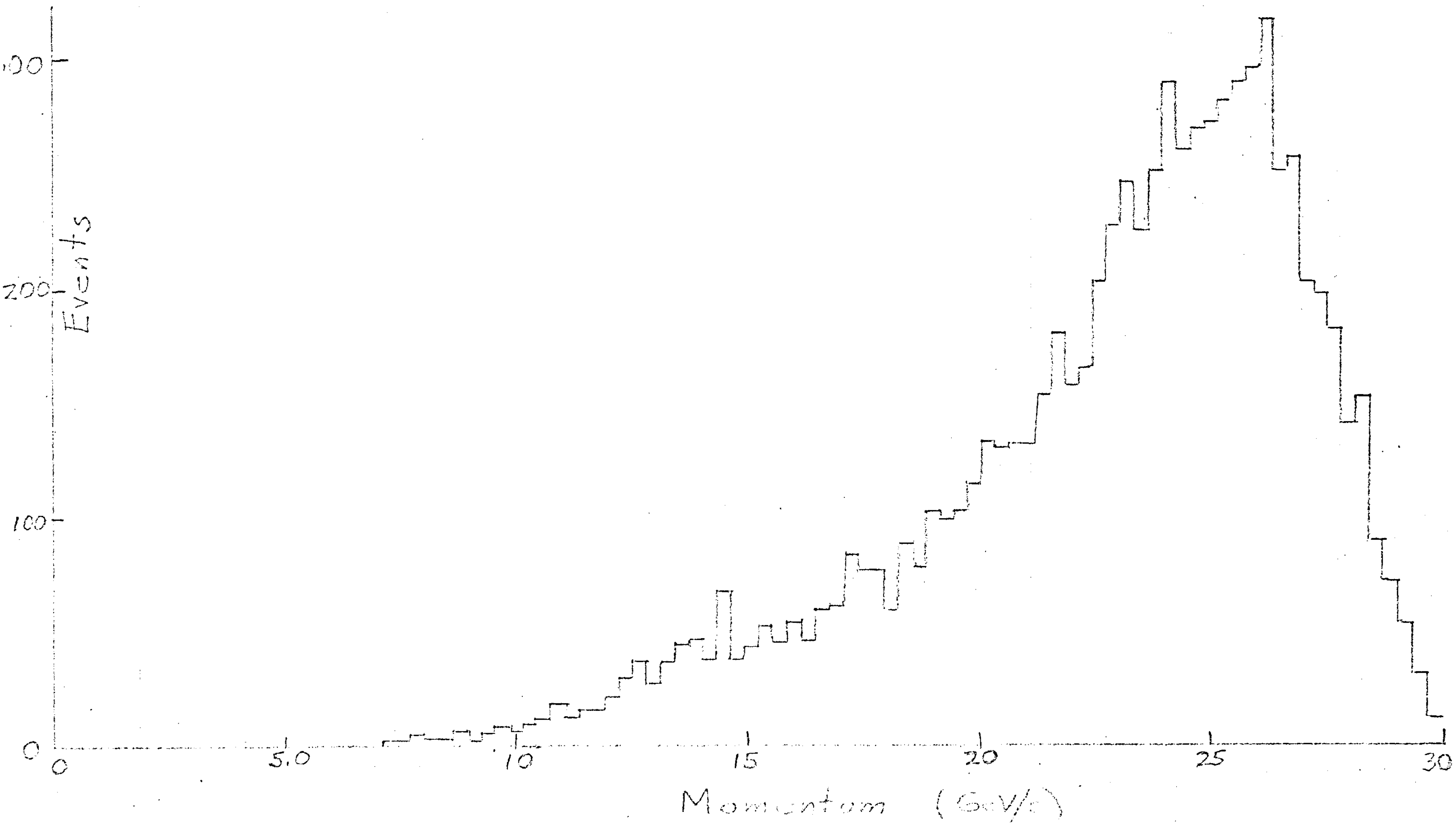


Figure 2

Uncorrected
neutron spectrum
from carbon target

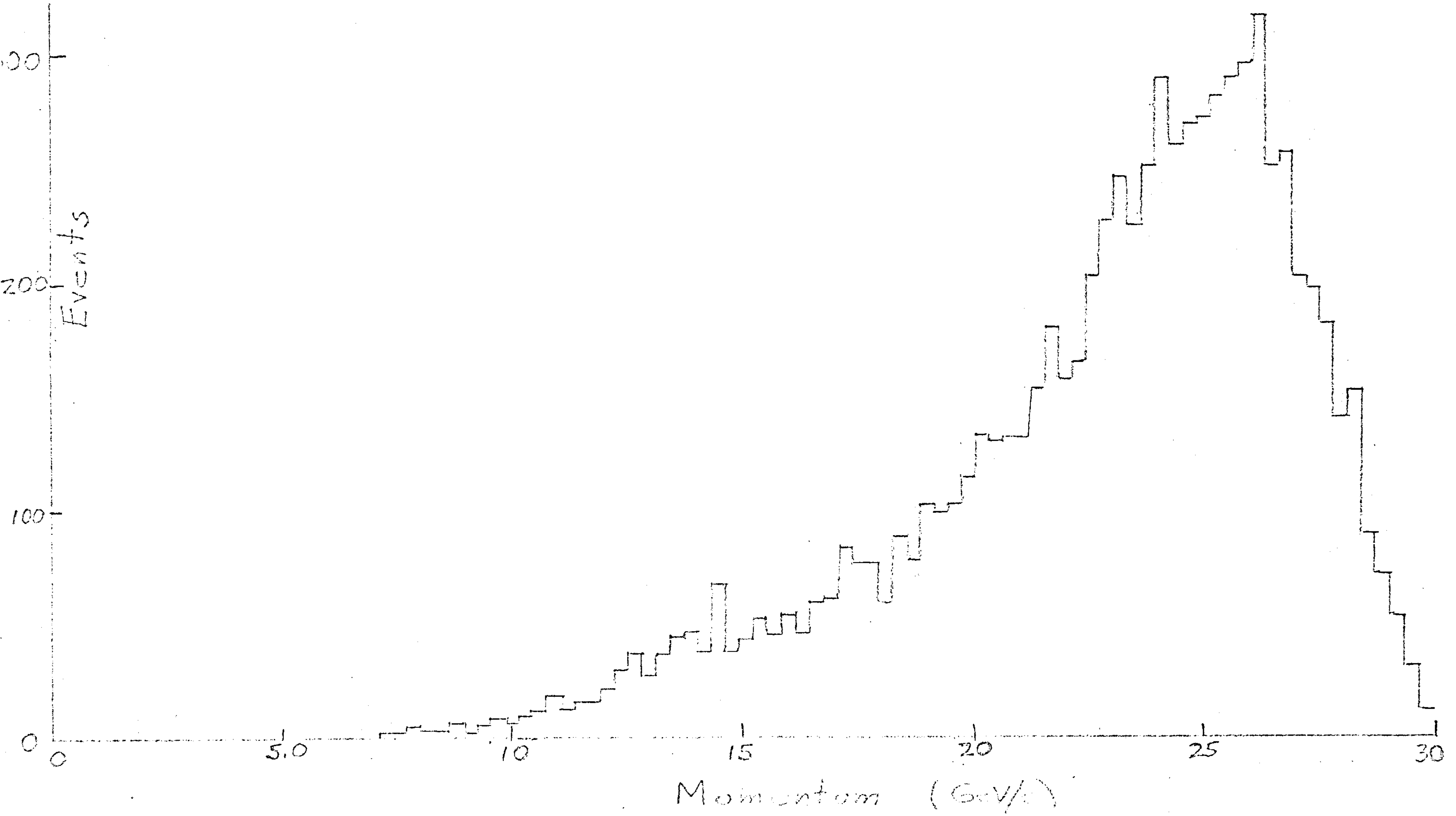


Figure 3a

t' distribution for Carbon

Target out background subtracted

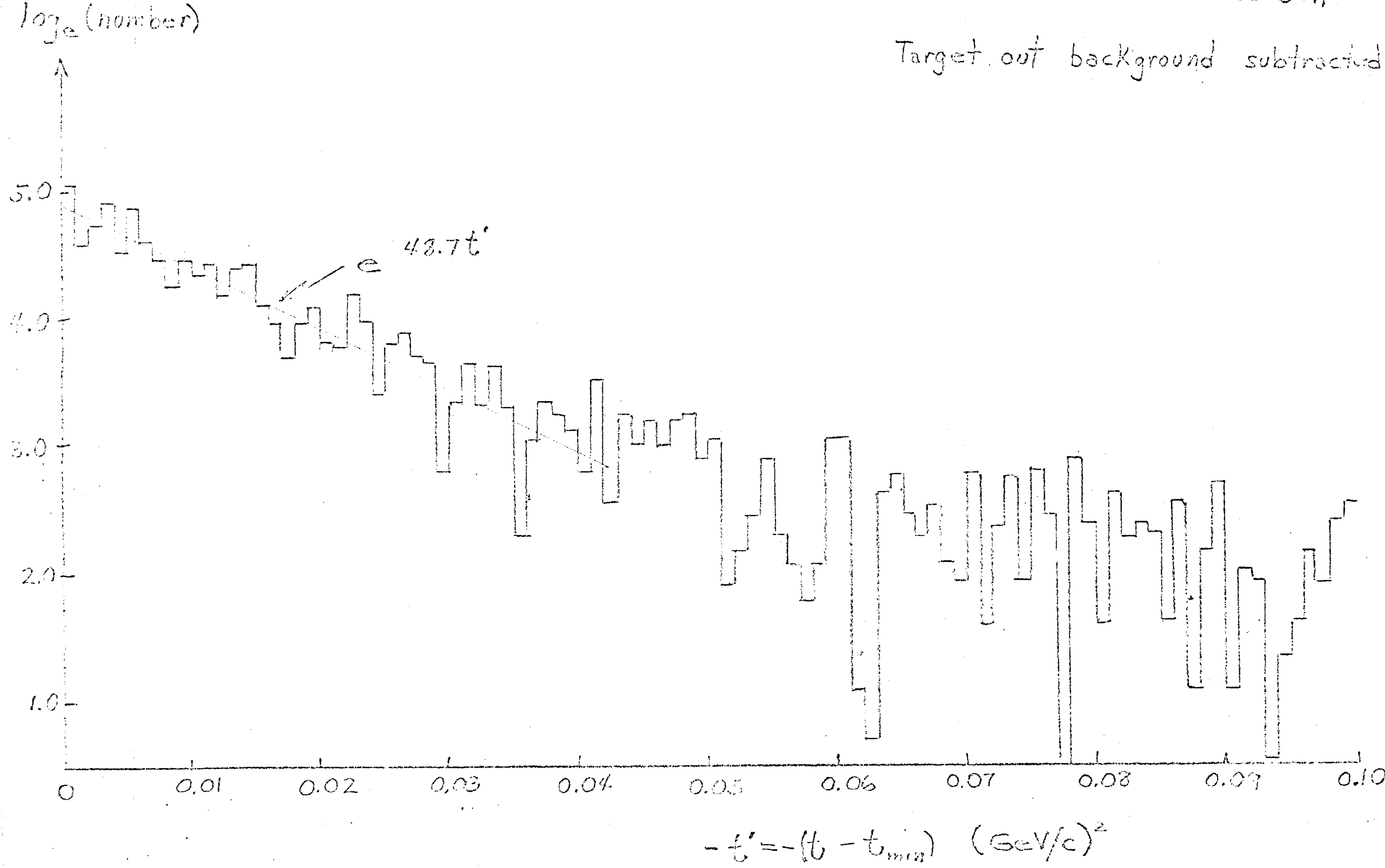
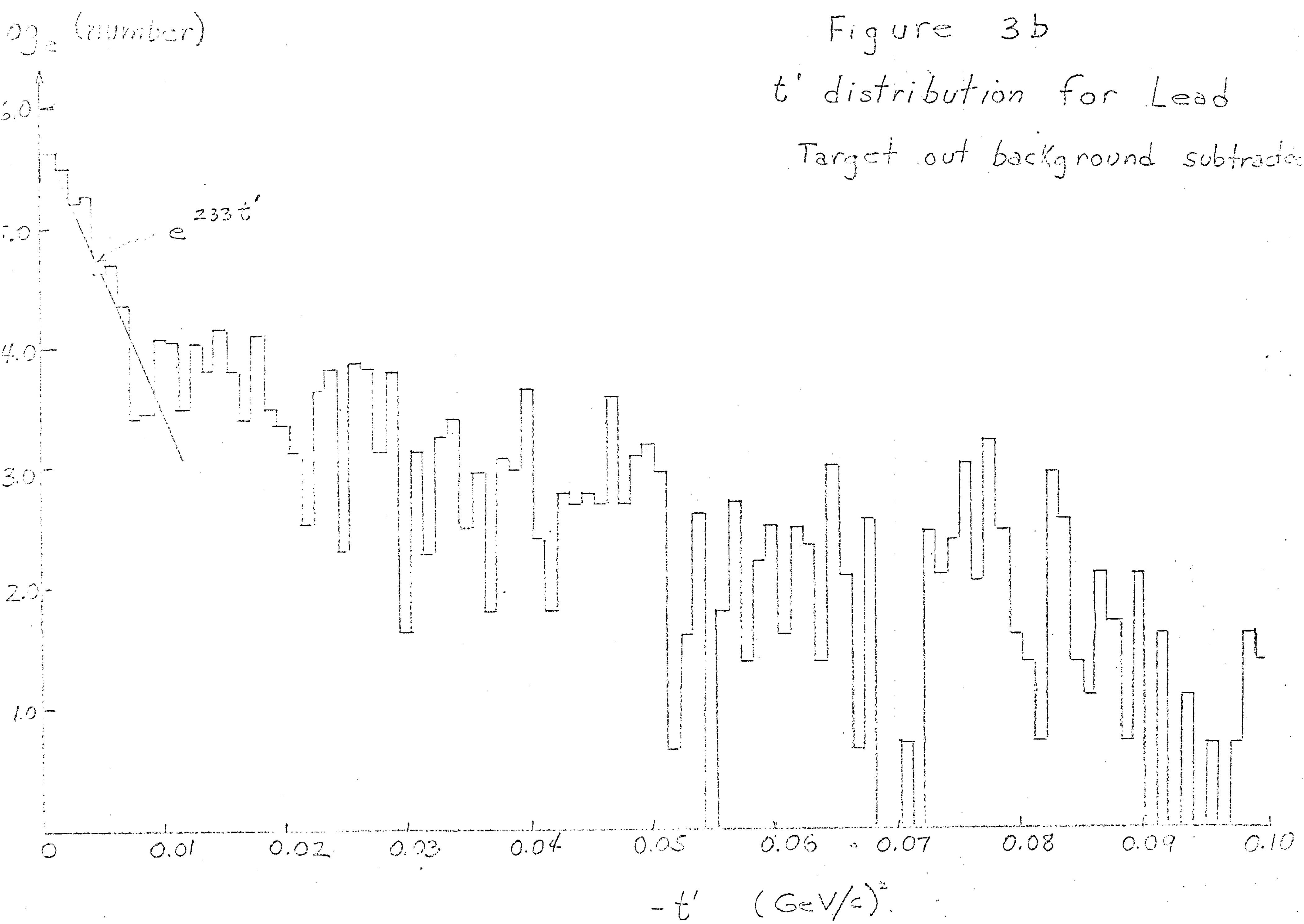


Figure 3b

t' distribution for Lead

Target out background subtracte[d]



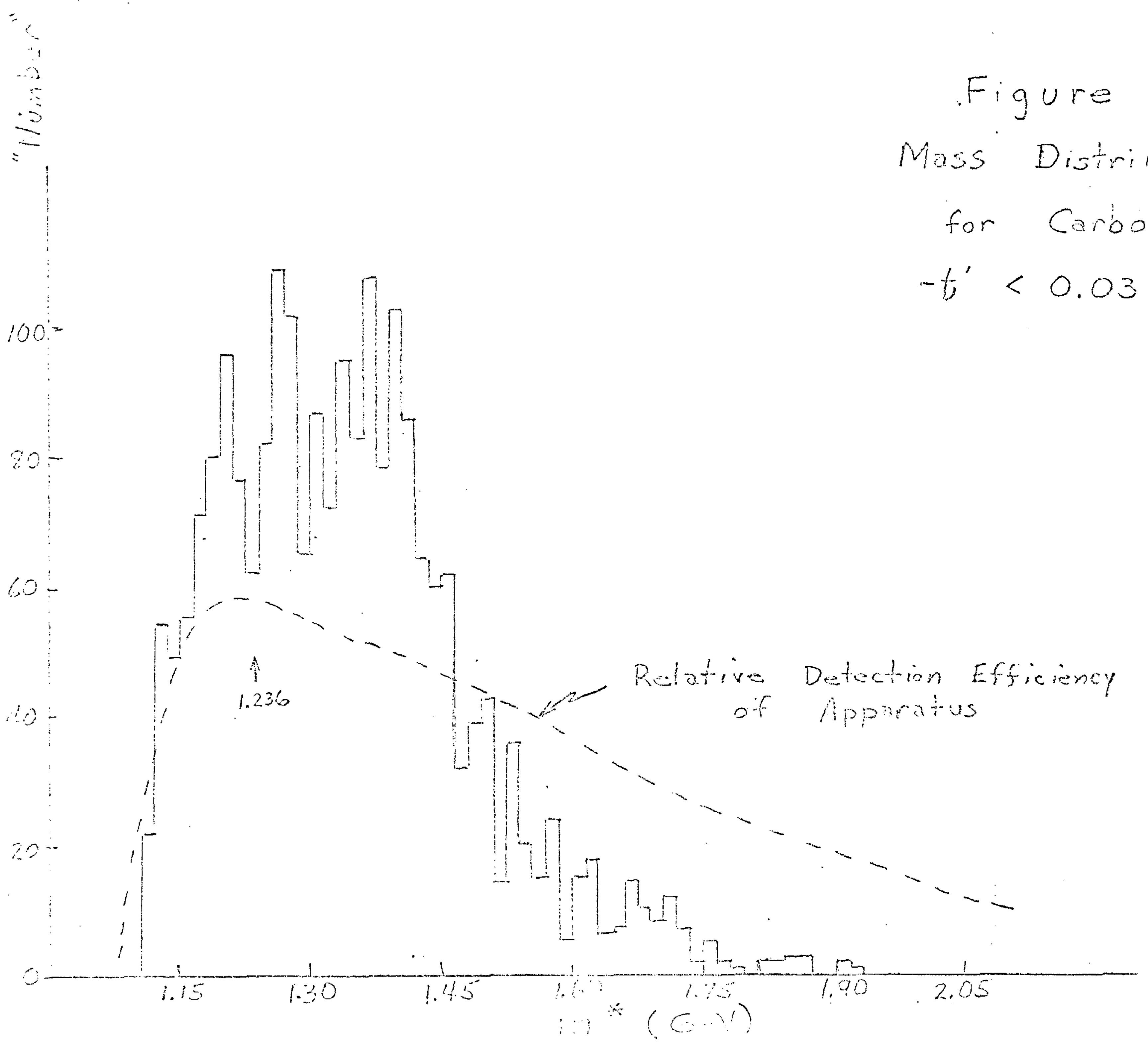


Figure 4 a
Mass Distribution for Carbon
$-t' < 0.03\ (GeV/c)^2$

Figure 4b

Mass Distribution for Lead

$-t' < 0.008 \ (GeV/c)^2$

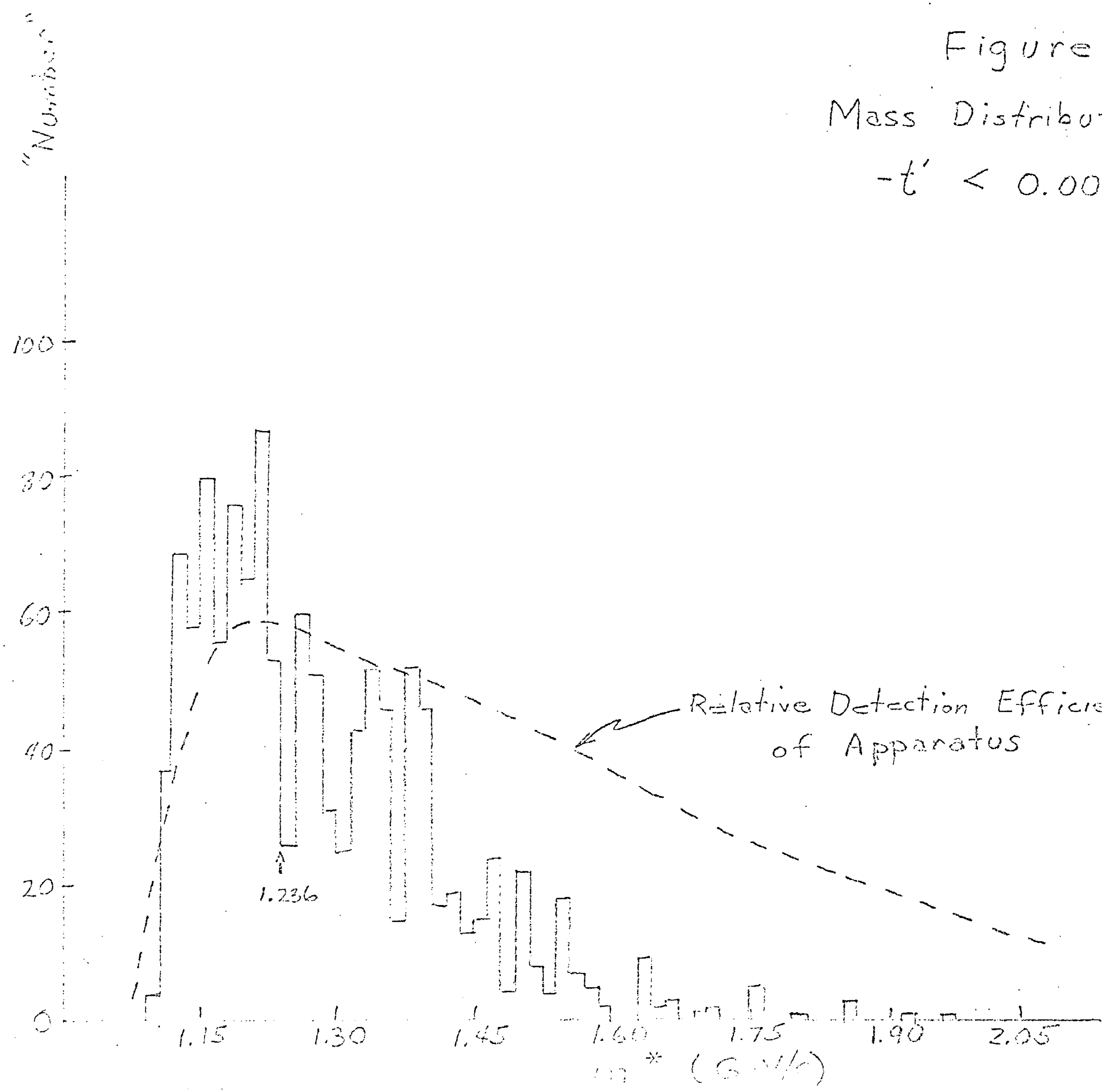
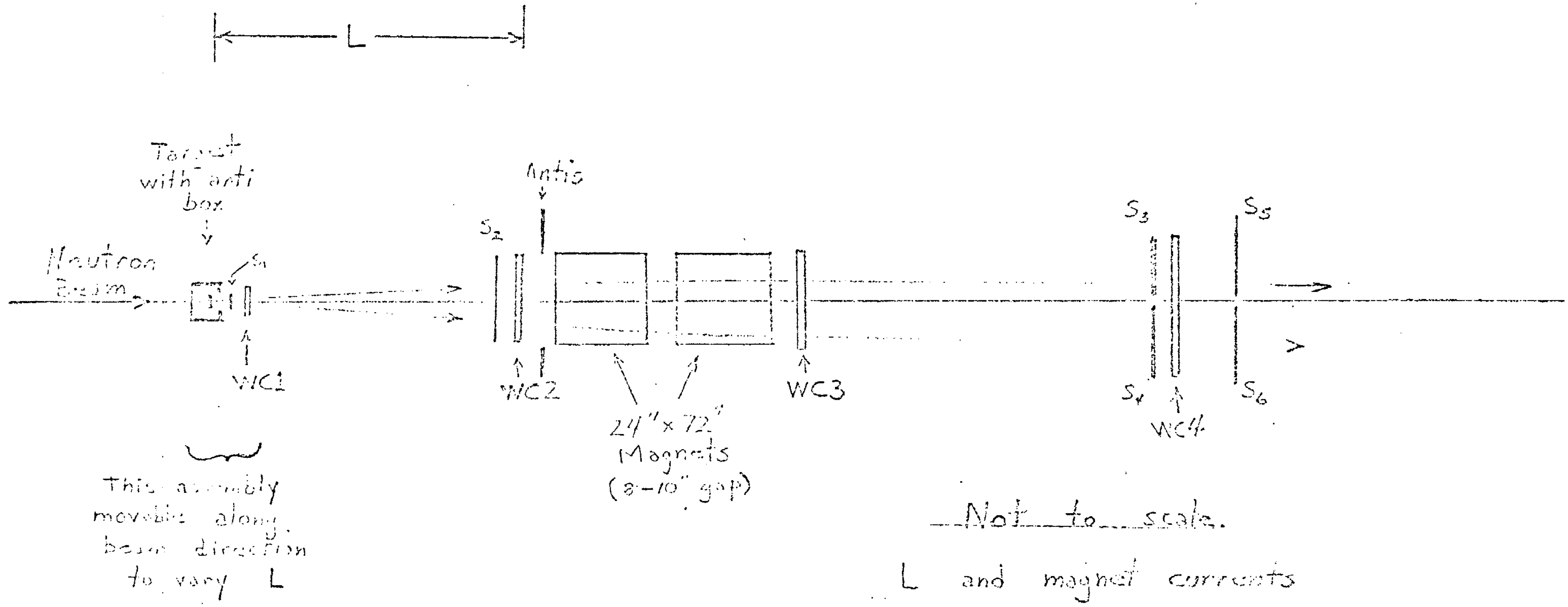


Figure 5

Possible arrangement for large m^*

S = Scintillation Counter
WC = Wire Chamber



Not to scale.

L and magnet currents are varied to optimize geometry for a particular range of m^*.

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

June 25, 1971

Dr. R. R. Wilson, Director
National Accelerator Laboratory
P. O. Box 500
Batavia, Illinois 60510

Ref. Proposal 112

Dear Dr. Wilson:

As Dr. Kreisler recently promised, I am enclosing a preprint of an article with results of our A.G.S. experiment to study neutron diffraction dissociation and Coulomb dissociation.

I had noted earlier that our A.G.S. data seemed to be in disagreement with the calculation of Nagashima and Rosen of the Coulomb dissociation of neutrons to the $\Delta(1236)$. That mystery has been cleared up by our recent realization that the peak of the $\Delta(1236)$ is badly distorted by dynamic factors and shifted to lower masses. We now believe that our data agree with the theoretical predictions both in shape and absolute magnitude.

I should emphasize that this development does not affect my criticisms of Rosen's proposal to study neutron total cross sections and $\overline{n}$ diffraction dissociation. The basic problem in the former is the low ratio of coherent events to triggers (which is unlikely to change materially between 25 and 170 GeV). In the latter it is the impossibility of distinguishing $n \rightarrow \pi^- + p$ events from $\overline{n} \rightarrow \pi^+ + \overline{p}$ with a zero-constraint fit.

In a certain sense I believe our objections to Rosen's experiment are strengthened because the Coulomb dissociation appears as expected and there is little reason to study it further (at least at N.A.L. energies).

I might also point out that in retrospect the greatest shortcoming of our A.G.S. experiment was its lack of coverage of a large range of decay angles (because of limitations on running time and equipment). This suggests the need for a relatively large solid-angle spectrometer or the use of several geometries (or both) in an N.A.L. experiment. This is also in line with our firm belief that an N.A.L. experiment should emphasize the large N* mass region accessible only at N.A.L.

Sincerely,

Michael J. Longo

Michael J. Longo

MJL:aa

P.S. I think it reasonable that the enclosed preprint be considered an appendix to Proposal 112. I am therefore sending a copy to Don Getz.

cc: D. Getz
~~M. N.~~ Kreisler

UM HE 71-19
June, 1971

Neutron Diffraction Dissociation and Coulomb Dissociation from Nuclei*

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**N.D.E.A. Fellow
+ Now at CERN, Geneva 23, Switzerland

ABSTRACT

We present preliminary results of a spark-chamber experiment to study the reaction

$$n+A \rightarrow (p+\pi^-)+A$$

where the $(p\pi^-)$ pair is produced coherently off the nucleus A. A 0° neutron beam derived from a beryllium target in the external beam of the A.G.S. was used. The mean effective momentum of the neutrons was about 23 GeV/c. Forward-going $(p\pi^-)$ pairs were detected in a wire spark-chamber spectrometer and the momentum and angles of each particle determined. The observance of a sharp forward peak (of width appropriate to the nuclear radius) indicated that a large fraction of the events were produced coherently.

Mass spectra for coherently produced events with carbon, copper, and lead targets are presented. The lead data show a peak at low masses due to Coulomb production of the $\Delta(1236)$. The most striking result of the experiment is the lack of any appreciable production of the well-established $I = \frac{1}{2}$ nucleon isobars.

We have carried out a spark-chamber experiment to study with good statistics the reaction

$$n+A \to N^{*o} + A \to (p+\pi^-) + A \qquad (1)$$

where the incident neutron dissociates into a $(p\pi^-)$ pair in scattering coherently off a nucleus A. The experiment was exploratory in nature since this process has never been observed with nuclear targets.[1] We present here our results for carbon, copper, and lead targets. The neutron beam, with a mean effective momentum of about 23 GeV/c, was taken off at 0° from a beryllium target in the external proton beam of the Brookhaven AGS. The data discussed in this article were taken with a proton momentum of 28.5 GeV/c.

The experimental arrangement is shown in Figure 1. The neutron beam with a diameter of approximately 2.2 cm was incident on the carbon, copper, or lead target. The target was surrounded by a rather complete anti shield (shown only schematically in Fig. 1) whose function was to veto events accompanied by charged particles or photons. A hole in the shield permitted charged particles produced near 0° to enter the spectrometer. The spectrometer consisted of a single 30"X72" magnet with a 6" gap and $\int B d\ell$ = 36 kG-m. The magnet was preceeded and followed by pairs of wire chambers. Each chamber had wire planes with horizontal wires, vertical wires, and ±45° wires so that a total of 16 coordinates were recorded per track. The chambers had a magnetostrictive readout with electronics capable of digitizing four sparks per line.

FULL PROPOSAL DISTRIBUTION

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

May 10, 1971

Dr. Frank Cole
National Accelerator Laboratory
P. O. Box 500
Batavia, Illinois 60510

Dear Frank:

Please note that Dr. Michael N. Kreisler of Princeton University is to be added to the list of experimenters on Proposal 112, Neutron Diffraction Dissociation and Coulomb-Dissociation from Various Nuclei. Dr. Kreisler will also replace me as spokesman for the experiment. Effective immediately, any correspondence concerning the proposal should be addressed to him at Princeton University.

Sincerely,

Michael J. Longo

Michael J. Longo

MJL:aa
cc: M. N. Kreisler
R. R. Wilson
J. Sanford

NAL PROPOSAL No. 0112

Correspondent: Michael J. Longo
Department of Physics
University of Michigan
Ann Arbor, Michigan

FTS/Off-net: 313-769-7100
764-4443

Neutron Diffraction Dissociation and Coulomb Dissociation from Various Nuclei

Michael J. Longo, H. R. Gustafson, Lawrence W. Jones
and John vander Velde

The University of Michigan

February 1971

The triggering requirement was $P_1L_2R_2\overline{A}$ or $P_1L_3R_3\overline{A}$ and was purposely kept simple to facilitate efficiency calculations. About 16% of the triggers contained two tracks from particles of opposite sign which appeared to come from the same point in the target. The spectrometer had a resolution of approximately ±1.2 mr in the opening angle of the pair and a momentum resolution of ±1.5% at 15 GeV/c.

Each two-track event was fitted to the hypothesis that it was from the reaction given in Eq.(1). Since the magnitude of the momentum of the incident neutron and the vector momentum of the recoil nucleus (or its fragments) were unknown, this is a zero-constraint fit. However the observation of a sharp forward peak of width appropriate to the size of the nucleus shows that the nucleus acted coherently and recoiled in a well-defined state for a large fraction of the events and that the contamination of the sample by processes other than $(p\pi^-)$ production is small. Figure 2 gives the distributions of the events in $t' \equiv (t-t_{min})$ for carbon and copper targets where $t' \cong -p_\perp^2$ and $t_{min} \cong -\frac{1}{4}\left[(m_{p\pi}^2-m_n^2)/p_n\right]^2$. A straight-line extrapolation indicates that incoherent backgrounds under the coherent peak are $\leqslant$30%, and the slopes are about those expected for these nuclei.

The momentum of the incident neutron can be calculated for each event [assuming reaction (1)]. Most of the events correspond to neutrons with momentum between 18 and 29.4 GeV/c with a mean momentum of approx. 22.8 GeV/c.

The $(p\pi^-)$ mass distributions obtained with carbon, copper and lead targets are shown in Fig. 3. The "target-out" background, typically about 30% of the total sample of events, has been subtracted. The geometric efficiency of the apparatus is also shown. The efficiency is almost independent of t' over the range studied and was determined from a Monte Carlo simulation which used the experimentally observed angular distribution for the decay of the "N*". The decay distributions were found to be anisotropic in the N* c.m. system. This makes it difficult to estimate the absolute efficiency of our apparatus accurately since the efficiency varied strongly with decay angle and the angular distribution outside the region in which we are sensitive is unknown.[2]

The mass resolution of our apparatus is typically ±10MeV at 1.2 GeV. This was calibrated by looking at e^+e^- pairs produced from a lead target by the small contamination of high-energy gammas in the beam.[3] The most striking result of the experiment is the apparent absence of any of the well-established $I = \frac{1}{2}$ nucleon isobars in the mass distributions.[4] This is true for all the nuclei studied over the entire range of four-momentum transfers within the coherent peaks [i.e., $-t' \leq 0.04\,(\mathrm{GeV}/c)^2$ for carbon, $-t' \leq .02\,(\mathrm{GeV}/c)^2$ for copper, and $-t' \leq .01\,(\mathrm{GeV}/c)^2$ for lead]. From the carbon data, assuming a smooth background, we can place upper limits on N*(1470) and N*(1688) of approximately 6% and 5% respectively of the total sample of events.

The total cross section for coherent dissociation into ($p\pi^-$) systems with masses between 1.078 GeV and 1.50 GeV is estimated at 1.1 mb, 2.5 mb, and 3.3 mb for carbon, copper, and lead respectively with a systematic uncertainty $\sim\pm 20\%$ in the relative cross sections and $\sim \binom{+100\%}{-\ 40\%}$ in the absolute cross sections because of the uncertainty in the decay distributions as discussed above.

The observed mass spectrum for lead shows a strong peaking at low masses. This can be accounted for by Coulomb dissociation of the neutron into the $\Delta(1236)$. Since the Coulomb production varies as Z^2 it is expected to be small for copper and negligible for carbon.[5] The shape of the $\Delta(1236)$ is badly distorted by dynamic factors and the peak is shifted to 1180 MeV. The dotted curve in Figure 3c shows the expected shape for Coulomb production of the $\Delta(1236)$ from lead as calculated from formulas in Ref. 5c using experimental data for pion photoproduction. A noncoulomb background similar in shape to the carbon data has been assumed as indicated by the light line in Fig. 3c. The agreement between the observed and calculated shapes for lead is excellent. About one-half of the events from lead are due to Coulomb production, and the observed Coulomb production cross section agrees with that expected to within a factor of two. As expected (Ref. 5), the data for lead for masses <1.3 GeV (where Coulomb production dominates) show a sharper t' dependence than that for masses >1.3 GeV (where diffraction dissociation dominates).

It does not seem possible to explain our carbon data in terms of overlapping resonances at 1300, 1470, 1520, and 1690 MeV as suggested by Morrison,[6] although a large number of overlapping resonances obviously cannot be ruled out. Our results are generally consistent with the picture that the diffraction dissociation is dominated by a "Deck effect" mechanism[7] in which the incident neutron virtually dissociates into a $(p\pi^-)$ pair and either the proton or pion scatters diffractively off the nucleus. This mechanism produces a broad enhancement of low masses in agreement with our results. The solid curve on Fig. 3a is from a Monte Carlo calculation based on such a model.[8] This picture also predicts anisotropic angular distributions in the rest system of the $(p\pi^-)$, again in agreement with our data.[9] Furthermore our mass distributions for carbon show little change in shape over the momentum range 15 to 29 GeV/c, again in agreement with the broad peak being due to a Deck-effect type of mechanism. (This also proves that the falloff in the mass spectrum above $\approx$1500 MeV is not due to a kinematic effect resulting from the increase of $|t_{min}|$ with increasing mass.)

In summary we have observed Coulomb dissociation of high-energy neutrons into the $\Delta(1236)$ off a lead target with a cross section about that expected. At neutron momenta $\sim$25 GeV/c the coherent diffraction dissociation off low Z nuclei proceeds almost solely through nonresonant dissociation with no appreciable production of isospin ½ nucleon resonances.

It is a pleasure to thank Norman Alders for his help in setting up the experiment and Thomas McCorriston for his assistance in measuring the neutron beam intensity.

References and Footnotes

1. For recent summaries of related data and their interpretation see:
   H. H. Bingham, Proceedings of the Topical Seminar on Interactions of Elementary Particles with Nuclei, Trieste, Sept. 1970. (See also CERN Report D.Ph.II/PHYS/70-60.)
   D.R.O. Morrison, CERN Report D.Ph.II/PHYS/70-64.
2. The apparatus is most sensitive to decays in which the π^- goes generally along the beam direction in the N* rest system. Typically the efficiency varies from nearly 100% for pions going forward (0°) to approximately 10% at 90°.
3. Almost all the gammas had energies <15 GeV. Cutting the data at 20 GeV effectively removed the gamma contamination.
4. There have been previous indications of a broad peak at low masses in the $N\pi$ system produced in both pp and πp collisions. See Reference 1.
5. (a) M. L. Good and W. D. Walker, Phys. Rev. 120, 1855 (1960).
   (b) Y. Nagashima and J. L. Rosen , University of Rochester Report UR-875-295, November 1969 (unpublished). Nagashima and Rosen predict a total cross section of 1.33 mb for $\Delta(1236)$ production and subsequent decay into π^-+p for 25 GeV/c neutrons incident on lead.
   (c) L. Stodolsky, Phys. Rev. Letters 26, 404 (1971).
6. D.R.O. Morrison, Reference 1.
7. R. T. Deck, Phys. Rev. Letters 13, 169 (1964).
   See also S. Drell and K. Hiida, Phys. Rev. Letters 7, 199 (1961). For a Reggeized version of a Deck-type model applied

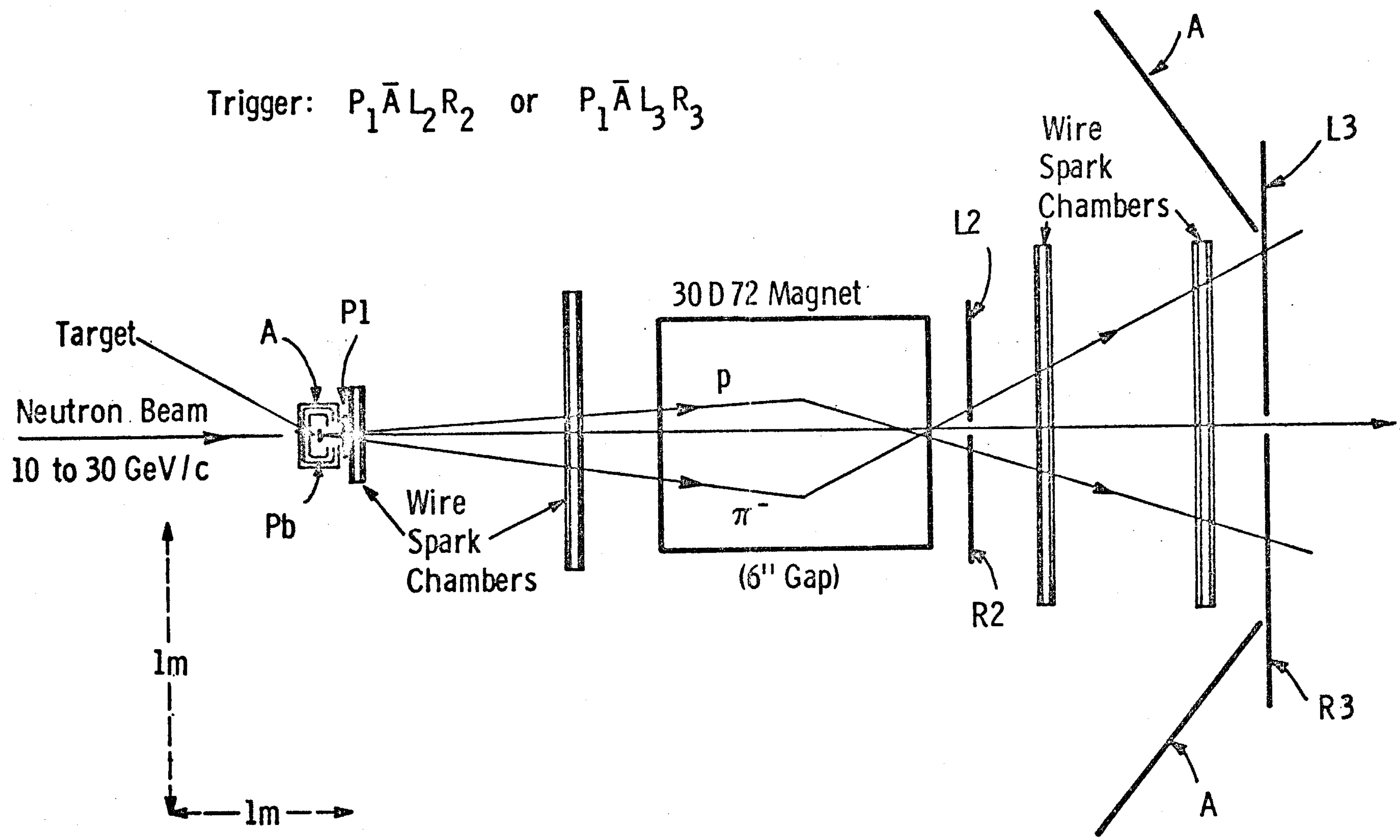
to a reaction similar to neutron dissociation, and references to more recent papers, see E.L. Berger, Phys. Rev. 179, 1567 (1969).

8. J. C. VanderVelde (unpublished).

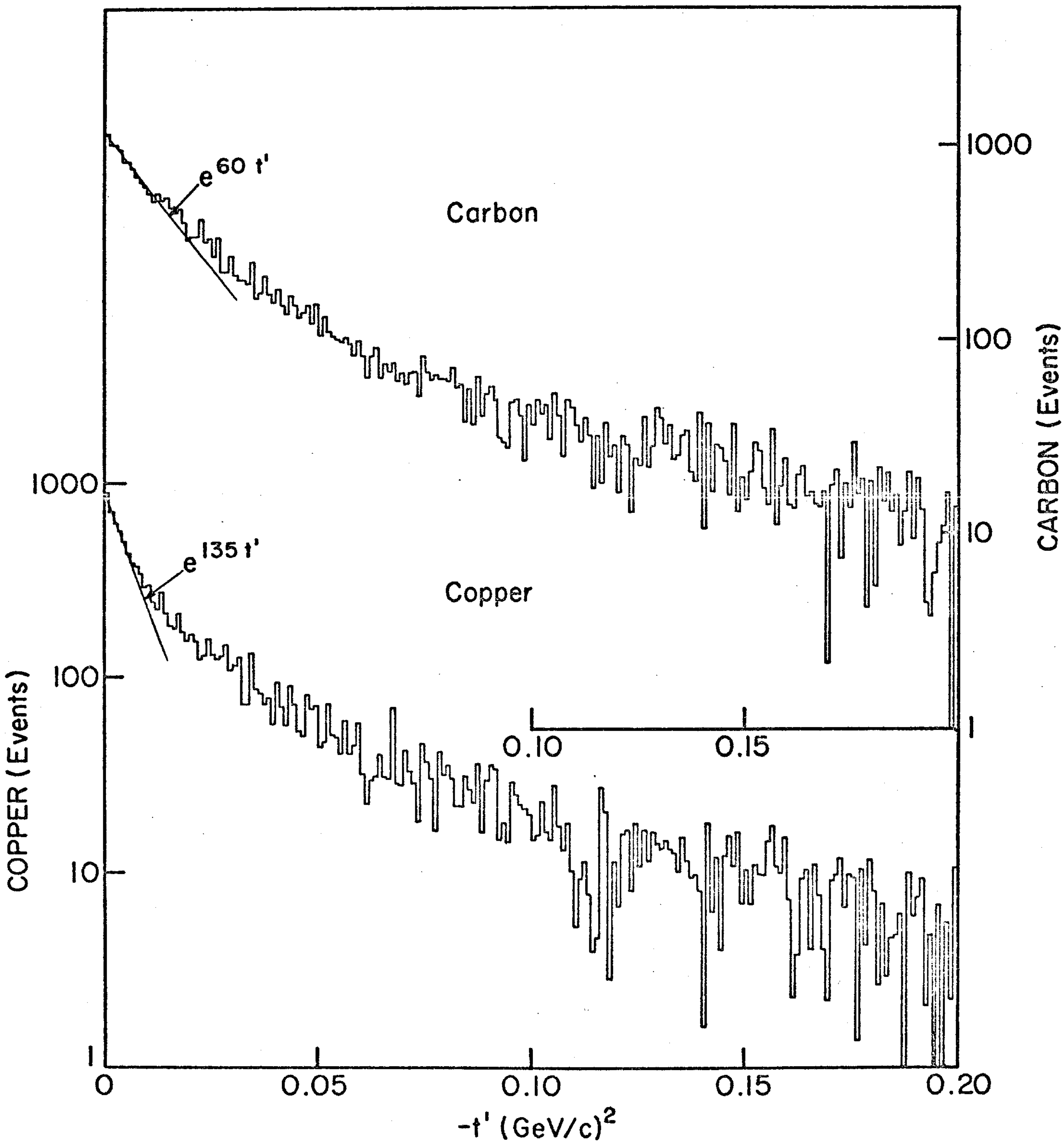
9. Results on the angular distributions will be published in a future article.

Figure Captions

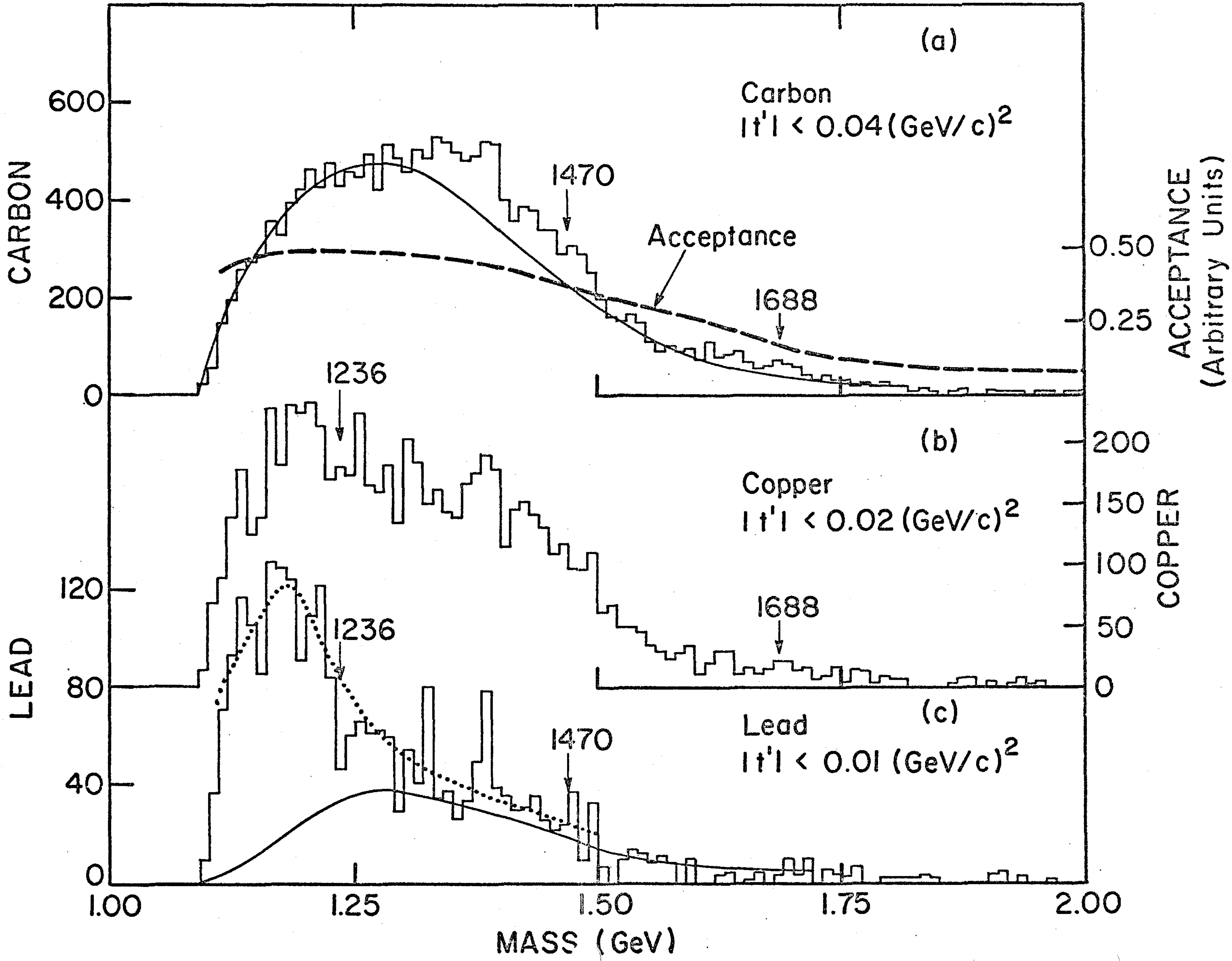
1. Schematic of experimental arrangement. Note different horizontal and vertical scales.
2. Distribution of events with t' for carbon and copper targets. "Target-out" background has been subtracted. The straight line is hand-fitted to the data at small t'. Expected values of b are $\approx 53 (\mathrm{GeV}/c)^{-2}$ for carbon and $\approx 160 (\mathrm{GeV}/c)^{-2}$ for copper.
3. Mass distributions (events per 10 MeV) for the $p\pi^-$ system observed with carbon, copper, and lead targets. The efficiency of the apparatus vs. mass, shown by the dashed curve in (a), has not been unfolded. The curves in (c) are explained in the text.



Trigger: $P_1\bar{A}L_2R_2$ or $P_1\bar{A}L_3R_3$
Target
A
P1
Neutron Beam
10 to 30 GeV/c
Pb
Wire
Spark
Chambers
30 D 72 Magnet
p
π^-
(6" Gap)
L2
R2
Wire
Spark
Chambers
A
L3
R3
A
1m
1m



$e^{60\,t'}$
Carbon
$e^{135\,t'}$
Copper
1000
100
10
1
0.10
0.15
CARBON (Events)
COPPER (Events)
0
0.05
0.20
$-t'\ (\mathrm{GeV}/c)^2$


(a)
Carbon
|t'| < 0.04 (GeV/c)^2
1470
Acceptance
1688
1236
(b)
Copper
|t'| < 0.02 (GeV/c)^2
1688
1236
(c)
Lead
|t'| < 0.01 (GeV/c)^2
1470
CARBON
LEAD
ACCEPTANCE (Arbitrary Units)
COPPER
MASS (GeV)
0
200
400
600
0
40
80
120
0.25
0.50
0
50
100
150
200
1.00
1.25
1.50
1.75
2.00